# ON THE DEVELOPMENT OF VISUAL PERCEPTION AND ATTENTION.[1]

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It is well known that a number of simultaneous impressions on the retina can be perceived when the time of exposure is so short as to exclude successive attention.[2] The extensive threshold, as the greatest number of objects thus seen may be called, varies with different individuals and doubtless many other conditions. The object of the experiments now to be described was to determine some of these conditions, especially those relating to the age and development of the observer. As the accuracy of perception clearly depends upon attention, I hoped also to obtain some data bearing upon the development of voluntary attention.

The apparatus used was constructed on the same principle as the gravity chronometer of Cattell and the tachistoscope of Volkmann and Wundt (see Figure 1). The objects to be perceived, which were letters, were pasted on white cardboard. This was placed on a wooden upright board. In front of this board is a movable screen of cardboard *AB*, with a rectangular opening, which, when allowed to fall past the objects, exposes them for the time taken by the opening in passing. The screen is let fall by the operator, who pulls the string attached to the clasp *M*. The noise of falling is greatly lessened by layers of felt in the screen holder *S*. The entire apparatus is hidden by a curtain *CD*, with a rectangular opening *OL*, where the stimulus *HK* appears. The

[1]The experiments to be described were partially planned in conjunction with Mr. S. H. Rowe, formerly Fellow in Education, Columbia College. On account of absence in Europe, Mr. Rowe was unable to continue the research.

[2]For previous investigations on the subject, see Cattell, *Philosophische Studien*, III, or *Brain*, XXXI.

advantage of the curtain is that an observer is ignorant of the movement of the screen, except as he perceives the objects exposed or the white background upon which they appear. In the centre of the opening of the curtain, and attached to the curtain by thread, is a small white cross *F*, serving as a fixation point. The entire apparatus is painted black. The time of exposure in these experiments was $\frac{1}{10}$ second.[1]

With this instrument the writer made a large number of experiments on school and college students, mostly from the

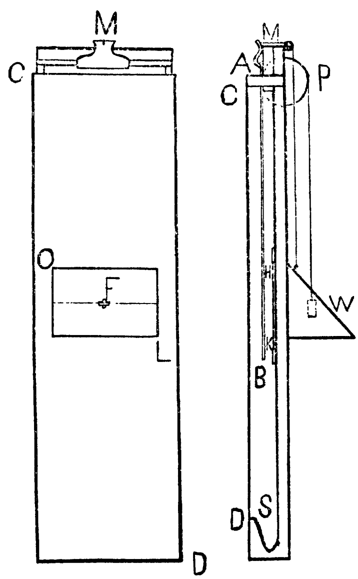


Fig. 1.

Horace Mann School of the Teachers' College and the School of Arts in Columbia College. Ten successive experiments were made on each group of observers, the number in a group varying from ten to thirty. The groups were arranged in approximately a triangular shape, so that all could see distinctly anything near the fixation point. In each experiment the stimuli were six capital letters arranged in two rows of three each, and presenting the appearance of an approximate square. The letters were printed for the purpose, and were 48 mm. in height. The combinations of letters were as fol-

[1]This time was obtained theoretically from the formulæ of mechanics.

lows: (i) YOG LNA, (ii) EVX MHK, (iii) UJR ZWD, (iv) NXA GFO, (v) DRK LSI, (vi) YZB CTP, (vii) JNW HVE, (viii) TSX LFA, (ix) CDI RGK, (x) OBP UJM. They were selected so as to avoid, if possible, any decided difference in the legibility of the different groups. For this purpose I used the results obtained by Prof. Cattell for the legibility of letters.[1] In conducting the experiment the observers were told to look at the fixation point when the signal "ready" was given, and to continue to look at the fixation point until the letters appeared, when they were to write down what letters they saw. They did not know how many letters would appear, and care was taken that they could not know when to expect the stimulus. The purpose of this was to test the observer's powers of prolonged attention. If he was not attending, at least to the extent of looking at the apparatus, he could not see anything.

The fact that some observers were necessarily in more favorable positions for seeing than others may, we think, be neglected. In the experiments on three different groups those unfavorably seated had about as good records on the average as those favorably seated.

In the experiments on the college students, the first that were made, the intervals of time between the signal and the appearance of the stimuli were $\frac{1}{10}$, 1, $\frac{1}{2}$, $1\frac{1}{2}$ and $\frac{1}{4}$ minutes, and the same for the second five of the ten experiments. As the results showed no effect of fatigue, and as the writer wished to obtain some data on the subject, in the succeeding experiments on pupils of the H. M. S.[2] the intervals were increased, being $\frac{1}{3}$, 3, 1, 4 and 2 minutes.

I now give the results of the experiments for the different classes, I being the lowest primary of the H. M. S. The high school pupils include four groups from the H. M. S. and two private schools,[3] and the college students include five groups from Barnard and Columbia Colleges.[4]

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[1]Cattell, *op. cit.*

[2]I will, for convenience, use this abbreviated form for the Horace Mann School.

[3]Mr. Browning's school for boys and Miss Gibbons' school for girls, both in New York.

[4]I take pleasure in here expressing my thanks to the school and college officers who have given me the opportunity to make these tests.

TABLE I.

Average Total Numbers of Letters Seen by Classes.

| N. | C. | S | MV. | R. | MV. | MAX. | MIN. | $\frac{R}{S}$ |
|---|---|---|---|---|---|---|---|---|
| 22 | I | 8 | 6 | 3 | 3 | 17 | 0 | .4 |
| 16 | II-III | 13 | 8 | 6 | 4 | 19 | 0 | .4 |
| 12 | IV | 16 | 6 | 7 | 3 | 13 | 1 | .4 |
| 17 | V | 18 | 5 | 14 | 4 | 22 | 3 | .8 |
| 17 | VI | 22 | 10 | 12 | 5 | 25 | 0 | .5 |
| 23 | VII | 19 | 7 | 14 | 5 | 23 | 0 | .7 |
| 23 | VIII | 25 | 7 | 21 | 6 | 37 | 8 | .8 |
| 84 | High | 30 | 5 | 23 | 6 | 47 | 4 | .8 |
| 75 | Coll. | 32 | 6 | 29 | 6 | 59 | 11 | .9 |

N. = number in class.
C. = class.
S. = average of total number of letters written down as seen in ten trials, six letters being given in each trial.
R. = average of total number seen correctly.
MV. = mean variation of S.'s or R.'s of the individual averages from the averages of the groups.
MAX. = maximum of total number seen correctly by any individual.
MIN. = minimum of total number seen correctly by any individual.

In table II are given the results for students classified according to age. The probable errors of the values of R. are given in the R. column, preceded by the sign $\pm$. The MV.'s for the R.'s only are given.

TABLE II.

Average Total Numbers of Letters Seen for Different Ages.

| N. | AGE. | S. | R. | MV. | MAX. | MIN. | $\frac{R}{S}$ |
|---|---|---|---|---|---|---|---|
| 39 | 7 - 9 | 11 | $4 \pm .4$ | 3 | 33 | 0 | .4 |
| 77 | 10 - 12 | 20 | $13 \pm .3$ | 3 | 32 | 0 | .6 |
| 73 | 13 - 15 | 24 | $18 \pm .6$ | 6 | 37 | 0 | .7 |
| 132 | 16[1] + | 32 | $27 \pm .4$ | 6 | 59 | 8 | .8 |

[1]Most of these observers were from 16 to 18 years of age.

From the above tables it is evident that the extensive threshold, or ability to receive and retain[1] a number of simultaneous, retinal impressions, is a function of individual growth, reaching its maximum only when the observer is fully developed.[2] The average number seen correctly in one trial by the adult observers was about three, whereas children from 7 to 9 saw but one. These numbers would be less if the element of chance were eliminated.[3] They would, on the other hand, probably be somewhat greater under more favorable conditions. In my experiments the observers did not know just when to expect the exposure, and, moreover, we must not expect such experiments to give results as exact as those of the laboratory. Practice increases the extensive threshold, and, as is shown by the columns MV. MAX. and MIN., great individual variations were observed. Very few adult observers saw five letters on the average, and some adults saw but two. The tendency to guess seems to decrease with maturity. The average mean variations of the separate observations of the individual observers from their averages were found to be about the same for the younger as for the older students. But the relative variation ($\frac{mv}{R}$) for the children of 10 to 12 was found to be about double that of the students of 16 and over. This is what we should expect, as it is a matter of common observation that children are deficient in power of constant attention.

A question of considerable interest is the relation of the pupil's range of perception to his intellectual capacity as judged by his teacher. I found that those rated A for mental capacity by the teachers, on an A, B, C basis, had somewhat higher averages than the others, and out of the twelve best observers (four from each age group) eight were rated A and but one C. There are, however, marked exceptions. One young lady of 18, known by the writer to be a brilliant student, saw but sixteen letters out of the sixty, and in no case more than three. Those marked A by their teachers for attention in class also excelled the others, but here also I found decided exceptions. Many pupils must have, therefore, good powers of attention even when they show no evidence of them to their teachers. No difference was found between

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[1]I will use this expression hereafter in the sense in which it is here used, without making any assumption as to its psychological interpretation.

[2]The same result for auditory memory and attention was found by Bolton. AMERICAN JOURNAL OF PSYCHOLOGY, Vol IV, No. 3.

[3]The probability of correctly guessing any one letter was for the older students about one third of the probability of writing down a letter correctly as found in the experiments, and for the younger students somewhat greater.

the girls and boys, the averages closely corresponding. Other investigators have found that the girls tend slightly to excel the boys in the tests given.[1] More extended experiments might, however, show a difference.

In order to investigate the question of fatigue, the averages were taken for each of the ten experiments for each group. The results for the experiments in which long times of waiting were used, one to four minutes, were somewhat better than those in which short times were used. This was found for both series of times, $\frac{1}{3}$, 3, 1, 4 and 2 minutes, and $\frac{1}{10}$, 1, $\frac{1}{2}$, $1\frac{1}{2}$ and $\frac{1}{4}$ minutes.

But fatigue of the visual centres must have been present, since several observers complained of pain in the eyes and even headache from the strain of attention. As the results were not appreciably affected, we conclude that the attention of children may be taxed to the extent of causing abnormal fatigue without any marked effect on the accuracy of perception. As it is, moreover, improbable that the long periods of waiting are more favorable for perception, or at least so much so as is indicated, we must infer that, despite precautions to avoid this, there are decided differences in the legibility of the different groups of letters. Practice cannot account for the results for experiments V and VI, the accuracy of observation for V being about 30% and 40% greater than for VI for the two time series. Nor can we ascribe the greater legibility of V to the difference in fatigue, for, on the one hand, in the case of the H. M. S. observers, the time of waiting for V was much longer than for VI; on the other, in the case of the college students and some others, the times for both were very short.[2] We infer, then, that one determining factor is the arrangement of the letters. But in neither case was a syllabic combination used, and the combinations of threes certainly do not make "sense." On the other hand, YZB and CTP, the letters used for VI, have much less similarity to combinations of letters in actual use than have DRK and LSI, those used in V. If this be the explanation, the combinations are perceived as units rather than as separate and distinct objects; or at least the mind tends to perceive them so, and is successful in proportion to the ease with which the perceptive processes of the separate letters are mutually helpful. From this it would follow that we do not, as has been supposed, see several things at once, but see the given stimuli as a unit and then analyze this unit

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[1]Bolton, *op. cit.* Jastrow, *Educational Review*, Dec., 1891.

[2]The same result was found for three private school groups not here included, as the times were not the same.

into its components. It is indeed possible that since the legibility of the letters depends upon the distinctness of the retinal images, some combinations of letters may not be so favorable as others for the formation of distinct retinal images of the different letters. It is interesting to note that in other experiments in which fatigue could play but a small part, the relation of V and VI was the same as in these.[1]

In the experiments described above, although verbal and syllabic combinations were avoided, several observers perceived certain combinations as words. Thus TSX LFA was read TEXAS, three times; OBP UJM was read JUMP, once; YOG LNA was read LONG, once, LONG WAY, once, and YOU, once; and UJR ZWD was read ARE, once. In a very few instances more letters were written down than were actually given. Three observers perceived the group first given as ABC, etc., the first letters of the alphabet.

A limited number of experiments were made with the same time of exposure, but with this difference, that one letter was exposed instead of six. The letters were CRYSNIXOJA. The times of waiting were $\frac{1}{20}$, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{3}{4}$, and $\frac{1}{6}$ minutes for the first five, and the same for the second five. The test was made on twenty-three high school pupils and on sixteen pupils of grade II in the primary department of the H. M. S. In the 230 observations (10x23) of the high school pupils, only seven letters were written down incorrectly; and in the 160 observations of the primary class only twenty-eight were not rightly perceived. The results show that the inability of the younger children to perceive the letters when six are given is due, not merely to the brief period of exposure, but also to the complexity of the stimulus.

A few experiments were also made in which six colors were used instead of letters. As the results were approximately the same, we may conclude that the inferences based upon the tests with letters are valid for the perception of objects in general and not for letters only.

The experiments I have described were all made with $\frac{1}{10}$ second exposure. I will now describe other experiments in which the time of exposure was one second. These experiments were made only on classes I-VIII inclusive of the H. M. S. and a group of high school students. The same apparatus was used, but was of course adapted to the change of time. This was done by attaching a heavy weight *W* to a cord which ran over a friction pulley *P* and was attached to the drop screen *AB* (see Figure 1). When the screen was allowed to fall, its velocity, and consequently the time of exposure, was regulated

[1] See later experiments with one second exposure.

by the weight on the principle of Atwood's machine. The same combinations of letters were used as in the $\frac{1}{10}$ second experiments, but several months elapsed between the two series of experiments. The experiment was conducted in the same manner, but short times of waiting only were used, 5, 30, 15, 45 and 10 seconds, and the same repeated for the second 5 experiments.

In the following table, I give the results of these experiments. The letters mean the same as in table I.

TABLE III.

Average total numbers seen with 1 second exposure for different classes.

| N. | C. | S. | MV. | R. | MV. | MAX. | MIN. | $\frac{R}{S}$ |
|---|---|---|---|---|---|---|---|---|
| 19 | I | 20 | 7 | 17 | 5 | 36 | 7 | .85 |
| 17 | II | 30 | 5 | 26 | 4 | 38 | 20 | .87 |
| 10 | III | 37 | 5 | 33 | 5 | 49 | 20 | .89 |
| 20 | IV | 35 | 5 | 28 | 6 | 48 | 14 | .77 |
| 15 | V | 40 | 7 | 36 | 6 | 43 | 25 | .90 |
| 22 | VI | 44 | 6 | 38 | 5 | 54 | 28 | .82 |
| 13 | VII | 51 | 8 | 44 | 8 | 58 | 29 | .86 |
| 11 | VIII | 50 | 8 | 47 | 7 | 59 | 31 | .94 |
| 10 | High | 59 | 2 | 55 | 6 | 60 | 40 | .93 |

The results show that the range of perception for one second exposure also depends upon individual growth. The brighter students tend to excel in these as in the $\frac{1}{10}$ second tests. This was found by two distinct methods, as before. There does not seem, however, to be any close connection between the two tests. The best observers in the one second tests include many that had poor records in the previous tests. But temporary conditions would cause some variation in the same observer.

As in the $\frac{1}{10}$ second experiments, variations were found in the accuracy of perception for the different combinations of letters. As the times of waiting were very short and as close attention was not necessary in order not to miss the letters, these differences cannot be ascribed to fatigue.

The relative variation was found to be fairly constant and to be but little greater for the children of the primary classes in the

one second tests than for the high school and college students in the $\frac{1}{10}$ second tests. But the relative variation for the younger pupils is at the same time much less in the one second than in the $\frac{1}{10}$ second tests. This is what one might expect, since, when the time of exposure is as long as one second, continuous concentration of the attention is not necessary as in experiments in which short times of exposure are given.

I have up to this point endeavored to make no assumptions as to the interpretation of the experiments described. The simplest interpretation is that the extensive threshold measures the number of objects that can be simultaneously grasped by consciousness. It is probable, however, that the process is quite complex. In fact the results found for the different combinations do not favor so simple an interpretation. The accuracy of the result may depend upon the reproductive processes involved, and the analysis of the memory image. It is possible also that the sensitiveness of the retina is a determining factor.

Whatever be the exact nature of the mental process, it is certain that the accuracy of perception and reproduction will depend to some extent upon the attention. In fact Wundt identifies the extensive threshold with attention.[1] From this point of view the results of the $\frac{1}{10}$ second experiments would measure the capacity of the observers for concentrated attention. It is quite true that attention is necessary in order to see the letters, but the assumption that it is the only factor is unwarranted. The results of the experiments certainly are not favorable to such an interpretation. No decrease in the number of letters seen was found for the longest times of waiting, which were such as to cause decided fatigue. Then many bright students proved to be poor observers, and it is improbable that students that excelled in their studies would be deficient in their powers of attention. But even if we assume that the experiments measure the attention, they do not necessarily measure the *capacity* for attention. Those interested in the experiments and desiring to excel would attend more closely than others. It is possible that the general superiority of the brighter students may be due to these causes; for children of the most active minds would be most interested in novel experiences. But although we cannot assume that the average number of letters seen by an observer measures his powers of attention, the mean variation from the average of the numbers seen in the different experiments is presumably due, principally at least, to variations in the attention.

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[1] Wundt's expression is "the extent of apperception," *Grundzüge d. Phys. Psy.*, IV[te] Aufl., II, 287.

With regard to the one second experiments, the conditions are more complex than in the others, but at the same time conform more closely to those of the perceptions of ordinary experience. The number of letters seen doubtless depends upon the degree of attention, but it also depends upon the readiness with which the attention is fixed, and the time of perception. The development of the visual memory may affect the results in both series of experiments. That there is a radical difference between the processes involved is made probable by the fact that some that excelled in one test did poorly in the other.